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METHOD FOR ASSISTING LOW-ALTITUDE NAVIGATION OF AN AIRCRAFT

The invention relates to low-altitude navigation of an aircraft.

Methods for assisting low-altitude navigation are already known for very maneuverable aircraft such as fighter planes. But they are not suitable for aircraft with limited maneuverability performance such as cargo airplanes and airliners.

Furthermore, the document EP 0775953 relating to a method for piloting a military transport airplane at low-altitude by analyzing the trajectory by successive segments having a maximum length less than twice a distance considered a priori as necessary for avoiding too frequent changes in slope is known. This analysis leads to a computational load more connected to the length of the trajectory than the nature of the relief being overflown.

A significant objective of the invention is therefore to propose a method for assisting safe, low-altitude navigation in three-dimensions (3-D) for an aircraft having limited performance aiming at making the computational load depend on the nature of the relief being overflown, such that for example flying above the side of a mountainous massif leads to fewer calculations than flying over a series of hills and valleys.

To reach this objective, the invention proposes a method for assisting low-altitude navigation of an aircraft equipped with a flight management system suited to determining a flight-plan ground-trajectory for the aircraft based on a sequence of straight and/or curved segments joining intermediate points on the

ground P at an altitude alt(P), where the ground trajectory takes into consideration the aircraft's performance and limitations, mainly characterized in that it comprises the following steps for the flight management system consisting in:

- for each point P on the ground trajectory, calculating a safe altitude, alt safe, to obtain a point P_{safe} such that

alt safe (P_{safe}) = Max[alt(P + lat mrg R), alt(P + lat mrg L)] +vert mrg,

where lat mrg R and L are respectively predetermined right and left lateral margins and vert mrg is a predetermined vertical margin,

- calculating a safe profile formed from safe segments joining the points P_{safe}

- extracting summit points S from among the points P_{safe} of the safe profile such that the K points located before S and after S have a safe altitude below that of S, K being a determined parameter,

- determining the aircraft's weight at these points S as a function of the distance along the safe profile between the aircraft and this point S and of the aircraft's consumption over this distance, where the consumption is an aspect of the aircraft's performance and limitations,

- for each point S, determining the maximum climb slope MaxClimbFPA that the aircraft can support to reach S and the maximum descent slope MaxDescFPA which the aircraft can support for following the lowest ground trajectory after having passed through S, as a function of the aircraft's performance and limitations and the weight, defining two performance segments which have a first end at S, slopes MaxClimbFPA and MaxDescFPA on either side of the point S and a second end at the point of intersection with the terrain or with another performance segment arising from another point S and

- calculating a performance profile formed from

CLAIMS

1. A method for assisting low-altitude navigation of an aircraft equipped with a flight management system suited to determining a flight-plan ground trajectory for the aircraft based on a sequence of straight and/or curved segments joining intermediate points on the ground P at an altitude alt(P), where the ground trajectory takes into consideration the aircraft's performance and limitations comprising the following steps for the flight management system consisting in:
   - for each point P on the ground trajectory, calculating a safe altitude, alt safe, to obtain a point P_{safe} such that
     alt safe (P_{safe}) = Max[alt(P + lat mrg R), alt(P + lat mrg L)] +vert mrg,

   where lat mrg R and lat mrg L are respectively predetermined right and left lateral margins and vert mrg is a predetermined vertical margin,
   - calculating a safe profile formed from safe segments joining the points P_{safe}

   characterized in that it further includes the following steps for the flight management system consisting in:
   - extracting summit points S from among the points P_{safe} of the safe profile such that the K points located before S and after S have a safe altitude below that of S, K being a determined parameter,
   - determining the aircraft's weight at these points S as a function of the distance along the safe profile between the aircraft and this point S and of the aircraft's consumption over this distance, where the consumption is an aspect of the aircraft's performance and limitations,

- for each point S, determining the maximum climb slope MaxClimbFPA that the aircraft can support to reach S and the maximum descent slope MaxDescFPA which the aircraft can support for following the lowest ground trajectory after having passed through S as a function of the aircraft's performance and limitations and the weight, defining two performance segments which have a first end at S, slopes MaxClimbFPA and MaxDescFPA on either side of the point S and a second end at the point of intersection with the terrain or with another performance segment arising from another point S and
- calculating a performance profile formed from performance segments and which makes it possible to associate at each point P of the safe profile a performance altitude, alt perf (P).

2. The method for assisting navigation as claimed in the preceding claim, characterized in that it further comprises the step consisting of determining a flyable low-altitude profile based on the safe profile and the performance profile.

3. The method for assisting navigation as claimed in the preceding claim, characterized in that the determination of the flyable low-altitude profile consists of calculating for each point P of the ground trajectory a low-altitude flight altitude, alt flight, for obtaining a point P_{flight} such that

$$\text{alt flight}(P_{flight}) = \text{Max}[\text{alt safe }(P), \text{alt perf }(P)],$$

where the flyable low-altitude profile is formed from segments joining the points P_{flight}.

4. The method for assisting navigation as claimed in one of the preceding claims, characterized in that it consists of sampling the points P according to a step p, and in that K is determined as a function of p and/or a threshold slope and/or the terrain and/or aircraft performance and limitations.

5. The method for assisting navigation as claimed in one of the preceding claims, characterized in that since the flight management system has an estimated position uncertainty, lat mrg R and L are determined as a function of the aircraft's performance and limitations and of the estimated position uncertainty.

6. The method for assisting navigation as claimed in one of the preceding claims, characterized in that since the flight management system has the wind speed and direction, aircraft speed, altitude of the terrain, and local temperature, the slopes MaxClimbFPA and MaxDescFPA are weighted as a function of the wind speed and direction and/or aircraft speed and/or altitude of the terrain and/or local temperature.

7. The method for assisting navigation as claimed in one of the preceding claims, characterized in that since the aircraft is equipped with engines, the slope MaxClimbFPA is calculated assuming an engine failure.

8. The method for assisting navigation as claimed in one of the preceding claims, characterized in that the flight management system being connected to a terrain database composed of grids having a predetermined width L, and comprising information

on the terrain's slope, it involves sampling the points P according to a step p determined as a function of the terrain's slope and the width L of the grids.

9. The method for assisting navigation as claimed in one of claims 2 to 8, characterized in that since a transition parabola is associated with the segments SegClimb and SegDesc of the flyable profile arising from a summit S, and since the top of the parabola is situated at ΔH from S, it consists in:
calculating a new summit S' located at ΔH above the summit S;
raising the transition parabola by ΔH; and
defining segments SegClimb' and SegDesc' arising from S' in a manner such that they are tangent to the raised transition parabola and obtain a new flyable profile.

10. A flight management system for an aircraft comprising a central unit (101) which communicates with an input-output interface (106), a program memory (102), a working memory (103), and a data storage memory (104), by means of data-transfer circuits (105), the input-output interface (106) being connected to a database (109) of the terrain to be flown over, characterized in that the program memory includes a program for implementing the method as claimed in one of the preceding claims.

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METHOD FOR ASSISTING LOW-ALTITUDE NAVIGATION OF AN AIRCRAFT

FIELD OF THE INVENTION

The invention relates to low-altitude navigation of an aircraft.

BACKGROUND OF THE INVENTION

Methods for assisting low-altitude navigation are already known for very maneuverable aircraft such as fighter planes. But they are not suitable for aircraft with limited maneuverability performance such as cargo airplanes and airliners.

Furthermore, the document EP 0775953 relating to a method for piloting a military transport airplane at low-altitude by analyzing the trajectory by successive segments having a maximum length less than twice a distance considered a priori as necessary for avoiding too frequent changes in slope is known. This analysis leads to a computational load more connected to the length of the trajectory than the nature of the relief being overflown.

A significant objective of the invention is therefore to propose a method for assisting safe, low-altitude navigation in three-dimensions (3-D) for an aircraft having limited performance aiming at making the computational load depend on the nature of the relief being overflown, such that for example flying above the side of a mountainous massif leads to fewer calculations than flying over a series of hills and valleys.

SUMMARY OF THE INVENTION

To reach this objective, the invention proposes a method for assisting low-altitude navigation of an aircraft equipped with a flight management system

suited to determining a flight-plan ground-trajectory for the aircraft based on a sequence of straight and/or curved segments joining intermediate points on the ground P at an altitude alt(P), where the ground trajectory takes into consideration the aircraft's performance and limitations, mainly characterized in that it comprises the following steps for the flight management system consisting in:

- for each point P on the ground trajectory, calculating a safe altitude, alt safe, to obtain a point P_{safe} such that

alt safe (P_{safe}) = Max[alt(P + lat mrg R), alt(P + lat mrg L)] +vert mrg,

where lat mrg R and L are respectively predetermined right and left lateral margins and vert mrg is a predetermined vertical margin,

- calculating a safe profile formed from safe segments joining the points P_{safe}

- extracting summit points S from among the points P_{safe} of the safe profile such that the K points located before S and after S have a safe altitude below that of S, K being a determined parameter,

- determining the aircraft's weight at these points S as a function of the distance along the safe profile between the aircraft and this point S and of the aircraft's consumption over this distance, where the consumption is an aspect of the aircraft's performance and limitations,

- for each point S, determining the maximum climb slope MaxClimbFPA that the aircraft can support to reach S and the maximum descent slope MaxDescFPA which the aircraft can support for following the lowest ground trajectory after having passed through S, as a function of the aircraft's performance and limitations and the weight, defining two performance segments which have a first end at S, slopes MaxClimbFPA and MaxDescFPA on either side of the point S and a second

end at the point of intersection with the terrain or with another performance segment arising from another point S and

- calculating a performance profile formed from

CLAIMS

1. A method for assisting low-altitude navigation of an aircraft equipped with a flight management system suited to determining a flight-plan ground trajectory for the aircraft based on a sequence of straight and/or curved segments joining intermediate points on the ground P at an altitude alt(P), where the ground trajectory takes into consideration the aircraft's performance and limitations wherein it comprises the following steps for the flight management system consisting in:
   - for each point P on the ground trajectory, calculating a safe altitude, alt safe, to obtain a point P_{safe} such that alt safe (P_{safe}) = Max[alt(P + lat mrg R), alt(P + lat mrg L)] +vert mrg,

   where lat mrg R and lat mrg L are respectively predetermined right and left lateral margins and vert mrg is a predetermined vertical margin,
   - calculating a safe profile formed from safe segments joining the points P_{safe}
   - extracting summit points S from among the points P_{safe} of the safe profile such that the K points located before S and after S have a safe altitude below that of S, K being a determined parameter,
   - determining the aircraft's weight at these points S as a function of the distance along the safe profile between the aircraft and this point S and of the aircraft's consumption over this distance, where the consumption is an aspect of the aircraft's performance and limitations,
   - for each point S, determining the maximum climb slope MaxClimbFPA that the aircraft can

support to reach S and the maximum descent slope MaxDescFPA which the aircraft can support for following the lowest ground trajectory after having passed through S as a function of the aircraft's performance and limitations and the weight, defining two performance segments which have a first end at S, slopes MaxClimbFPA and MaxDescFPA on either side of the point S and a second end at the point of intersection with the terrain or with another performance segment arising from another point S and

- calculating a performance profile formed from performance segments and which makes it possible to associate at each point P of the safe profile a performance altitude, alt perf (P).

2. The method for assisting navigation as claimed in the preceding claim, wherein it further comprises the step consisting of determining a flyable low-altitude profile based on the safe profile and the performance profile.

3. The method for assisting navigation as claimed in the preceding claim, wherein the determination of the flyable low-altitude profile consists of calculating for each point P of the ground trajectory a low-altitude flight altitude, alt flight, for obtaining a point P_{flight} such that

$$\text{alt flight}(P_{flight}) = \text{Max}[\text{alt safe }(P), \text{alt perf }(P)],$$

where the flyable low-altitude profile is formed from segments joining the points P_{flight}.

4. The method for assisting navigation as claimed in claim 1, wherein that it consists of sampling the

points P according to a step p, and in that K is determined as a function of p and/or a threshold slope and/or the terrain and/or aircraft performance and limitations.

5. The method for assisting navigation as claimed in claim 1, wherein since the flight management system has an estimated position uncertainty, lat mrg R and L are determined as a function of the aircraft's performance and limitations and of the estimated position uncertainty.

6. The method for assisting navigation as claimed in claim 1, wherein since the flight management system has the wind speed and direction, aircraft speed, altitude of the terrain, and local temperature, the slopes MaxClimbFPA and MaxDescFPA are weighted as a function of the wind speed and direction and/or aircraft speed and/or altitude of the terrain and/or local temperature.

7. The method for assisting navigation as claimed in claim 2, wherein since the flight management system has the wind speed and direction, aircraft speed, altitude of the terrain, and local temperature, the slopes MaxClimbFPA and MaxDescFPA are weighted as a function of the wind speed and direction and/or aircraft speed and/or altitude of the terrain and/or local temperature.

8. The method for assisting navigation as claimed in claim 3, wherein since the flight management system has the wind speed and direction, aircraft speed, altitude of the terrain, and local temperature, the slopes MaxClimbFPA and MaxDescFPA are weighted as a function of the wind speed and direction and/or aircraft speed and/or altitude of

the terrain and/or local temperature.

9. The method for assisting navigation as claimed in claim 4, wherein since the flight management system has the wind speed and direction, aircraft speed, altitude of the terrain, and local temperature, the slopes MaxClimbFPA and MaxDescFPA are weighted as a function of the wind speed and direction and/or aircraft speed and/or altitude of the terrain and/or local temperature.

10. The method for assisting navigation as claimed in claim 5, wherein since the flight management system has the wind speed and direction, aircraft speed, altitude of the terrain, and local temperature, the slopes MaxClimbFPA and MaxDescFPA are weighted as a function of the wind speed and direction and/or aircraft speed and/or altitude of the terrain and/or local temperature.

11. The method for assisting navigation as claimed in claim 1, wherein since the aircraft is equipped with engines, the slope MaxClimbFPA is calculated assuming an engine failure.

12. The method for assisting navigation as claimed in claim 2, wherein since the aircraft is equipped with engines, the slope MaxClimbFPA is calculated assuming an engine failure.

13. The method for assisting navigation as claimed in claim 3, wherein since the aircraft is equipped with engines, the slope MaxClimbFPA is calculated assuming an engine failure.

14. The method for assisting navigation as claimed in claim 4, wherein since the aircraft is equipped

with engines, the slope MaxClimbFPA is calculated assuming an engine failure.

15. The method for assisting navigation as claimed in claim 1, wherein the flight management system being connected to a terrain database composed of grids having a predetermined width L, and comprising information on the terrain's slope, it involves sampling the points P according to a step p determined as a function of the terrain's slope and the width L of the grids.

16. The method for assisting navigation as claimed in claim 2, wherein the flight management system being connected to a terrain database composed of grids having a predetermined width L, and comprising information on the terrain's slope, it involves sampling the points P according to a step p determined as a function of the terrain's slope and the width L of the grids.

17. The method for assisting navigation as claimed in claim 3, wherein the flight management system being connected to a terrain database composed of grids having a predetermined width L, and comprising information on the terrain's slope, it involves sampling the points P according to a step p determined as a function of the terrain's slope and the width L of the grids.

18. The method for assisting navigation as claimed in claim 4, wherein the flight management system being connected to a terrain database composed of grids having a predetermined width L, and comprising information on the terrain's slope, it involves sampling the points P according to a step p determined as a function of the terrain's slope

and the width L of the grids.

19. The method for assisting navigation as claimed in claim 2 to 18, wherein since a transition parabola is associated with the segments SegClimb and SegDesc of the flyable profile arising from a summit S, and since the top of the parabola is situated at ΔH from S, it consists in:
calculating a new summit S′ located at ΔH above the summit S;
raising the transition parabola by ΔH; and
defining segments SegClimb′ and SegDesc′ arising from S′ in a manner such that they are tangent to the raised transition parabola and obtain a new flyable profile.

20. A flight management system for an aircraft comprising a central unit which communicates with an input-output interface, a program memory, a working memory, and a data storage memory, by means of data-transfer circuits, the input-output interface being connected to a database of the terrain to be flown over, wherein the program memory includes a program for implementing the method as claimed in one of the preceding claims.